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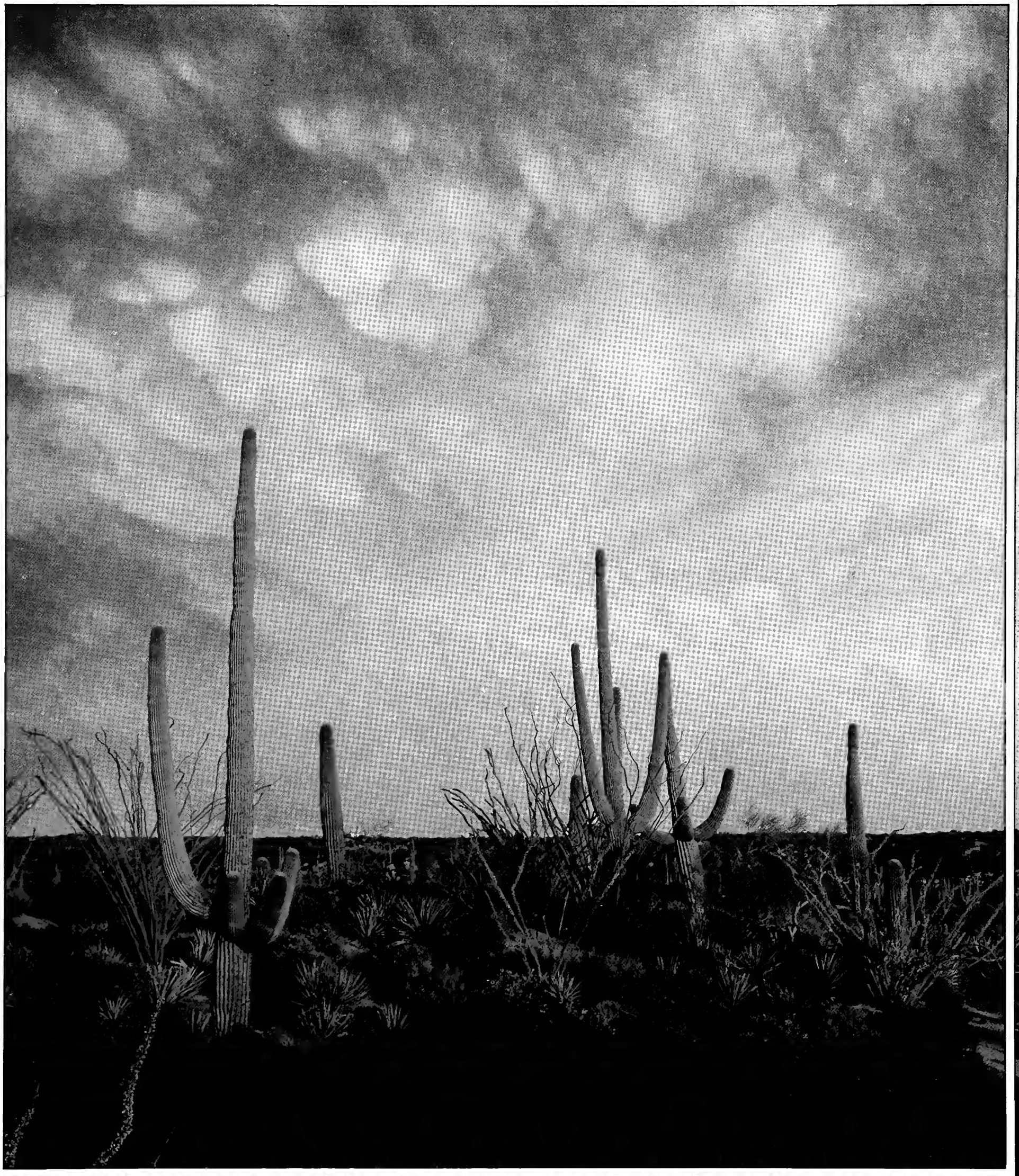

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The Garden wishes to thank Jerry Sieve for providing photographs for this issue of *Agave*. A resident of Cave Creek, Arizona, Sieve's special affinity with the Sonoran Desert is evident in his work.

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The Sonoran Desert:

THE LAND AND ITS PEOPLE

by Robert G. Breunig and Gary Paul Nabhan

Drought is the major news story this summer. The first five months of 1988 have been the hottest and driest on record in this country. Even more disturbing than the impact of the current drought is the very real probability that this is not just an isolated or cyclical event. It appears to be part of a global trend of climatic change due to the greenhouse effect.

If climatologists are correct in their predictions there will be a three-to-eight degree (Fahrenheit) rise in global temperatures by the year 2030. Fresh water reservoirs will shrink in size and the rate of groundwater recharge may slow, while ocean levels are likely to rise. The availability of fresh, uncontaminated water for human consumption and for irrigation will be limited.

Because of groundwater overexploitation during the last fifty years, the burgeoning population of arid lands will not be able to rely so heavily on this backup water supply to cushion it from droughts. And the human population of deserts is increasing dramatically. In the last quarter-century, an additional 184 million people have come to depend on the resources of these fragile, arid environments.

In our own country, the massive population shift to the sunbelt since World War II has been the greatest human migration in history. Take a look around the Phoenix metropolitan area where the Desert Botanical Garden is located — one cannot miss the tangible indicators, both good and bad, that this development has brought to our desert landscape since 1952.

In Phoenix, urbanization has caused a warming of summer temperatures *three times as great* as the warming trend in rural areas of nearby Pinal County, Arizona. By transforming our landscape from desert to city, we have changed the very climate in which we live and work.

Given the unprecendented scale of these changes, it might seem by comparison that historic patterns of desert living would have nothing to teach us. Many people believe that earlier desert dwellers did not change the landscape at all, compared to modern intervention. But human beings have always had an impact on desert lands — by hunting the herbivores, which shaped the vegetation; by opening up springs into riparian oases and transplanting wild food plants there; or by clearing, burning or irrigating their fields.

We must be careful not to create an artificial dichotomy — that non-western (native) peoples have always lived in total harmony with the land while western (European) peoples have always preached dominion over nature. No history lesson is ever that black-and-white.

> "Our work, our thinking, our lives, our culture and social activities are shaped by the influences of the country in which we reside. Arizonans are a desert people."
>
> *Forrest Shreve,*
> at the dedication of the
> Desert Botanical Garden.

During the last 12,000 years or more that humans have lived in the Southwest, each of their activities has had some degree of impact on the land, depending on the tools they used and the scale and duration of the activity. Some paleo-ecologists have provided evidence that the first southwestern hunting cultures played a key role in the extirpation of a number of large mammals. Although this hypothesis remains controversial in some circles, we cannot rule out the possibility that hunting has long shaped the vegetation here by selectively changing the mix of shrub browsers, grass grazers and seed dispersers.

Whatever the cause, the disappearance of large mammals meant the loss of a major food source, and the emerging Desert Culture shifted its diet to smaller game, wild grains, fruits, pods, tubers and greens. From 9,000 B.C. to 1 A.D., hunter-gatherers in the Sonoran Desert probably lived in small bands, collecting resources over a wide area on a seasonal cycle. Burning undoubtedly became one of their management tools for driving wildlife into kill sites and promoting the growth of certain fire-responsive food plants.

About 500 B.C. (although this date may be off a few centuries either way) something altogether new developed in the Sonoran Desert. Domesticated crops, introduced from Mexico, began to be planted in moist microhabitats. Corn, in particular, gradually became a dietary staple. Land clearing, water diversion, and then canal construction altered floodplain landscapes, transforming them into agricultural and riparian patchworks.

In Classic Hohokam times, agriculture began to expand beyond the floodplains as agaves were cultivated in terraces and rockpiles on bajadas and on mountain slopes across the desert. Confirming an earlier hypothesis by Paul and Suzanne Fish, Desert Botanical Garden researchers recently discovered remnant crops of *Agave murpheyi* still growing on Hohokam-built terraces. Such terraces and fields once covered tens of thousands of upland acres that are now considered too dry and rocky for the practice of modern agriculture.

Although the Hohokam civilization eventually collapsed, it persisted successfully in this very difficult environment for nearly a thousand years, far longer than our modern sunbelt civilization has to date. If there is a lesson to be learned from this long-lived culture, it is that they may have been well-adapted until they became too centralized and therefore too vulnerable. Their hundreds of miles of canals in the Salt River Valley, originally developed as small, separate irrigation systems, coalesced through time into one mega-system with canals as wide as those of the present Salt River Project. The entire population of the valley may have become dependent on a single supply and delivery system that was too large for their inherent ability to control it, given the unpredictability of droughts and floods in this desert. The Hohokam also became dependent on a trade network for ceremonial goods and status items. Perhaps this trade network failed, contributing to the collapse of the system. Whatever the ultimate

*"But the voice of the desert is the one which has been least often heard. We came to it last, and when we did come, we came principally to exploit rather than to listen." — **Joseph Wood Krutch***

cause, the Hohokam way of life rapidly deteriorated soon after it had reached its zenith in centralization.

Today we, too, are dependent on a trade network, one which brings virtually all of our food in from other states and countries. If our food supply and delivery system were to break down for even a month, our modern desert communities would be imperiled.

However, we have imported not only our food but our concept of what a habitable landscape should look like, and this has placed an enormous strain on our natural resources. In an atavistic attempt to impose cultural traditions rooted in the Old World, we have leveled the land, superimposed it with a rectangular grid, revegetated it with turfgrasses and exotic trees and plants, and created artificial lakes surrounded with park-like expanses of grassy lawns.

Historically, when a culture comes to a new land and lives in the environment long enough, that culture develops an affinity with the land that shapes its own identity. Our tenure on this desert land has been very short, but with modern technology, massive intervention and land modification we can completely transform the Sonoran Desert and

> "On the desert floor, giant mesquite, ironwood, acacias and paloverdes thrived on the dependable water supply. Mountain canyons harbored cottonwood, willow, ash and sycamore. Until this century the streams ran year round."
>
> *Charles Bowden*

destroy it before we have a chance to reach that level of understanding and appreciation of the land as it is.

The fundamental question for us then, as a culture, may be whether or not we can change our attitudes toward this desert land and truly become its natives. If we are to do this, we can begin by developing a deeper appreciation for the rich flora of the Sonoran Desert.

We can make it a part of our community identity by using native plants in public places, along freeways, and in median strips. We can make the desert part of our own lives by using native trees, shrubs and wildflowers in our home landscapes.

But this is only a beginning. In the near future we must master the process of restoration ecology and make an effort to restore some of the desert lands that have been badly degraded through thoughtless and uninformed practices of the past.

We can, for example, repair and revegetate parts of South Mountain Park that have been scarred by off-road vehicle use. Or, an enlightened community might be willing to support the restoration of the Salt River to a natural riparian state as an affordable alternative to the recently defeated Rio Salado Project.

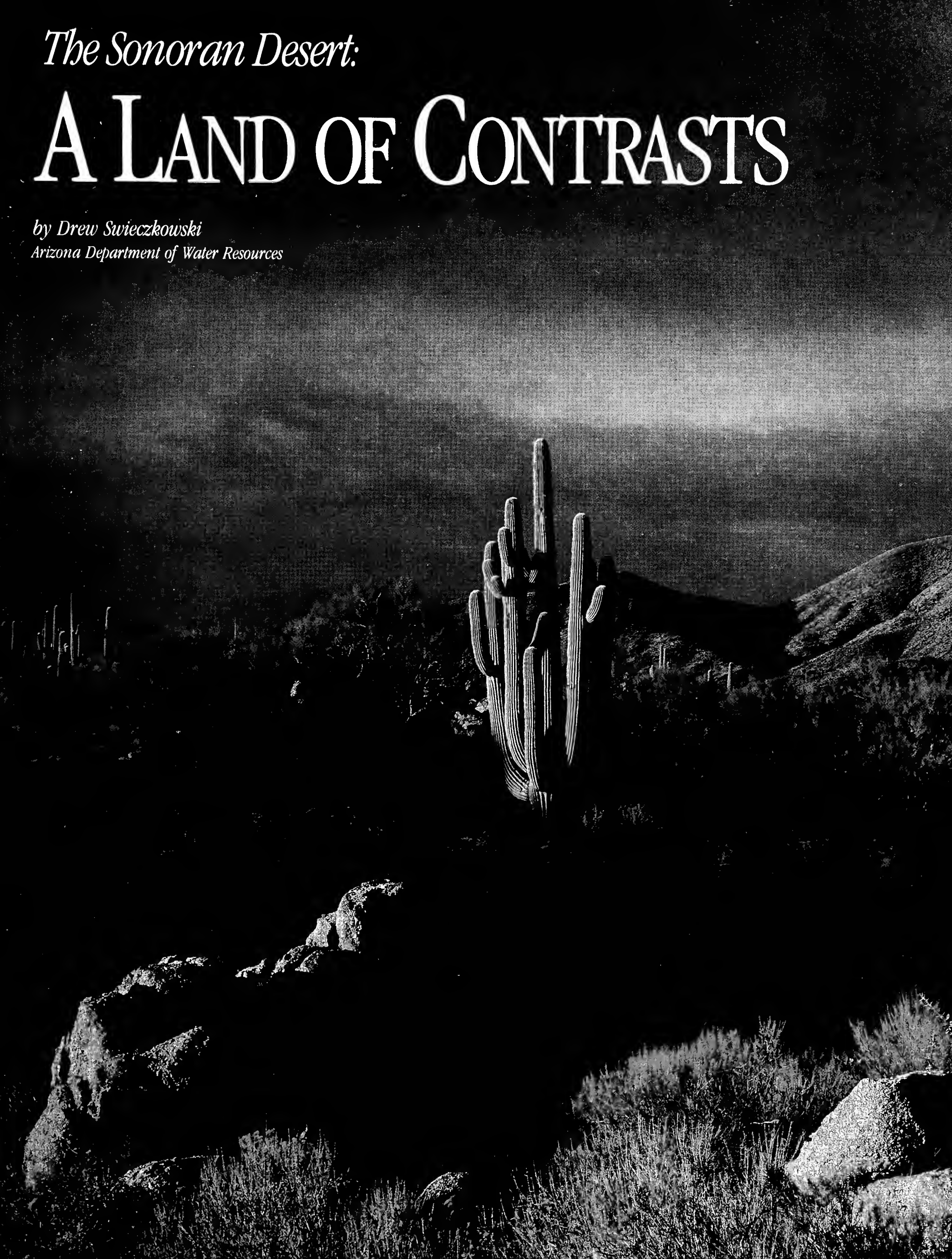
Finally, renewed, vigorous efforts must be made to set aside and preserve as many unspoiled tracts of the Sonoran Desert as are left so that natural biological processes can continue without human interference.

Through such measures as these, we can begin to integrate our modern society into the desert in which we live. Then future generations can look back upon our efforts and acknowledge ours as the culture that came to terms with the land and, like the Native Americans before us, called the desert our home.

The Sonoran Desert:

A Land of Contrasts

by Drew Swieczkowski
Arizona Department of Water Resources



SHAPING THE LAND ...

From the lush riparian environment along some stream channels to the dry Algodones Sand Hills west of Yuma, to the ocean coast of the Baja Peninsula, the variety in landscapes of the Sonoran Desert is immense. The natural environment, including the geology and water resources, also has great diversity.

The third largest of the four North American deserts, the Sonoran Desert has a total area of roughly 120,000 square miles with approximately 30 percent of its area inside of Arizona. The remaining 84,000 square miles is divided among the Mexican state of Sonora with 33 percent, Baja Mexico with 29 percent and a small portion in southeastern California with 8 percent. Annual rainfall for most of this desert is generally small, with an estimated range of five to twenty inches. Most annual rainfall measures less than fifteen inches. Temperatures range from below freezing in the winter months to above 110 F. in the hottest summer months. A great contrast in elevations also exists, from approximately 200 feet above mean sea level in the valleys to 3,500 feet on the mountains.

The geologic history of the Sonoran Desert began approximately five to twenty-five million years ago, roughly between the time of the extinction of dinosaurs and the first record of man. Its development began simply, with faulting or cracking of the earth's surface from tensional or pulling forces. These forces caused large blocks of land to be down-dropped, leaving behind mountain highs along with the lowered basins. Associated with this mountain and basin building activity was volcanism, evidence of which can be seen in most places in the Sonoran Desert. The Superstition Mountains east of Phoenix are a good example of this volcanic activity.

From the early development to the present day, several geological processes have been at work to shape the landscape into what the human eye sees today. Erosion of the mountain peaks has been the largest contributing factor. Water from sporadic yet sometimes heavy rainfall causes much of the erosional process, either eroding the rock by the powerful force of its flow, called fluvial action, or by expanding in rock fractures when it freezes during the colder times of the year. Sediments were carried down from the mountains to fill the earlier formed basins. In Arizona, some of the basins contain over 10,000 vertical feet of sediments deposited by this fluvial action.

Wind action, called eolian action, has also helped to transport and erode very fine materials such as sands or clay sediments. The large sand dunes west of Yuma, Arizona are a good example of this transporting power of wind.

Some other striking geological features of the Sonoran Desert can be seen as one transverses its landscape. Looking up to the mountains from the valley floors one can usually see alluvial fans. These develop from eroded materials carried down from the mountain highs by running water and deposited on the edge of the valley floors in a fan-type shape. When several of these fans join together they form a bajada, or a large sediment-filled sloping surface along a mountain front. A pediment is another erosion-controlled feature. This can be seen as a sloping surface in front of a mountain made up of bedrock with small deposits of sediments overlying it.

WATER ... A PRECIOUS LIFE FORCE

The one natural resource of the Sonoran Desert that is vital to both the biotic and human communities is water. Surface water and groundwater are found on both sides of the international border and play an important role in the development and maintenance of agricultural and municipal economies. Many large expanses of once dry and barren desert are now productive due to the development of the water resources. Thus, it is very easy to understand why Sonoran Desert dwellers must preserve and maintain an adequate supply if the future here is to continue to be bright.

Surface water is an integral component of the Sonoran Desert environment. Not only is it a powerful shaper of the landscape, it is also critical for the survival of both nature and human life. Since early times, desert dwellers have tried to capture and utilize surface water resources. The early Hohokam culture utilized the Salt River near what is now Phoenix, delivering water through extensive canal systems for agriculture and domestic uses. The early non-Indian settlers of the Sonoran Desert also looked to the rivers as a source of water but soon found them to be both uncontrollable and at times, unreliable.

As technology advanced, dams were constructed to help control, store and regulate the surface water. A series of dams was built on the Salt and Verde river systems for this very reason. Many other dams can also be found on the major waterways. There are twelve major river systems in the Sonoran Desert: seven in Mexico and four in the United States. Only one major river, the Colorado, is shared by both countries.

An important aspect of many of the permanent perennial streams of the Sonoran Desert is that they usually have watersheds that are outside of the desert area. Watersheds are the areas that capture precipitation for the rivers and are usually the place of origin of the river. Watersheds that contribute to desert streams generally have larger drainage areas

of higher elevation and precipitation than the internal drainage area of the desert. The Colorado River, for example, has an immense watershed which covers much of the western United States. This watershed has much greater precipitation than any region in the desert area.

Surface waters in the Sonoran Desert can also be categorized as ephemeral, meaning that they flow only during periods of precipitation. This is exemplified by the presence of many arroyos and dry washes in the area. Ephemeral streams are created from internal drainage within the desert and are too unpredictable for any long-term human use. These ephemeral streams, as mentioned before, are a powerful shaper of the landscape. Surface water can also be intermittent in nature. Intermittent surface waters may flow during much of the year but cease when dry periods prevail. These intermittent streams can be utilized for many agricultural and municipal water needs.

In examining the surface water resources of the Sonoran Desert it becomes apparent that this is a life-line for many agricultural and metropolitan areas. However, as surface water becomes totally appropriated, or when it is not physically available, humans in the past and in present times look to the water under their feet — groundwater. To many people, groundwater is a mysterious natural resource that lies deep beneath the earth's surface. There are many misconceptions about groundwater. Some imagine that it it a river running beneath the surface, or a large underground lake. Actually, groundwater is contained in the pore spaces of the unconsolidated basin sediments. It is found in what is called the saturated zone, or aquifer.

Before human appearance in the Sonoran Desert, groundwater was in equilibrium. Surface water in the form of streams and precipitation entered into the ground through gravity seepage and was collected and stored in the form of groundwater. After many years of additive storage, the groundwaters reached a state of equilibrium where the natural discharge (outflow) equaled the seepage of surface waters into the ground (recharge). The water level in the aquifer at that time was near the surface and usually (when in contact with a stream) contributed base-flow or groundwater outflow to perennial stretches of rivers throughout the desert area.

The first human influence on the groundwater system began at the turn of the century when shallow, hand-dug wells were constructed to withdraw near-to-the-surface groundwater. As technology and the need for groundwater expanded, machine drilled wells were sunk deeper and more often into the aquifer below. As the total withdrawals of groundwater increased, the equilibrium was disturbed and the water levels eventually began to be lowered further beneath the ground-level surface. Inflow to the aquifers from natural sources such as precipitation and stream channel recharge could not keep up with the groundwater pumped as outflow.

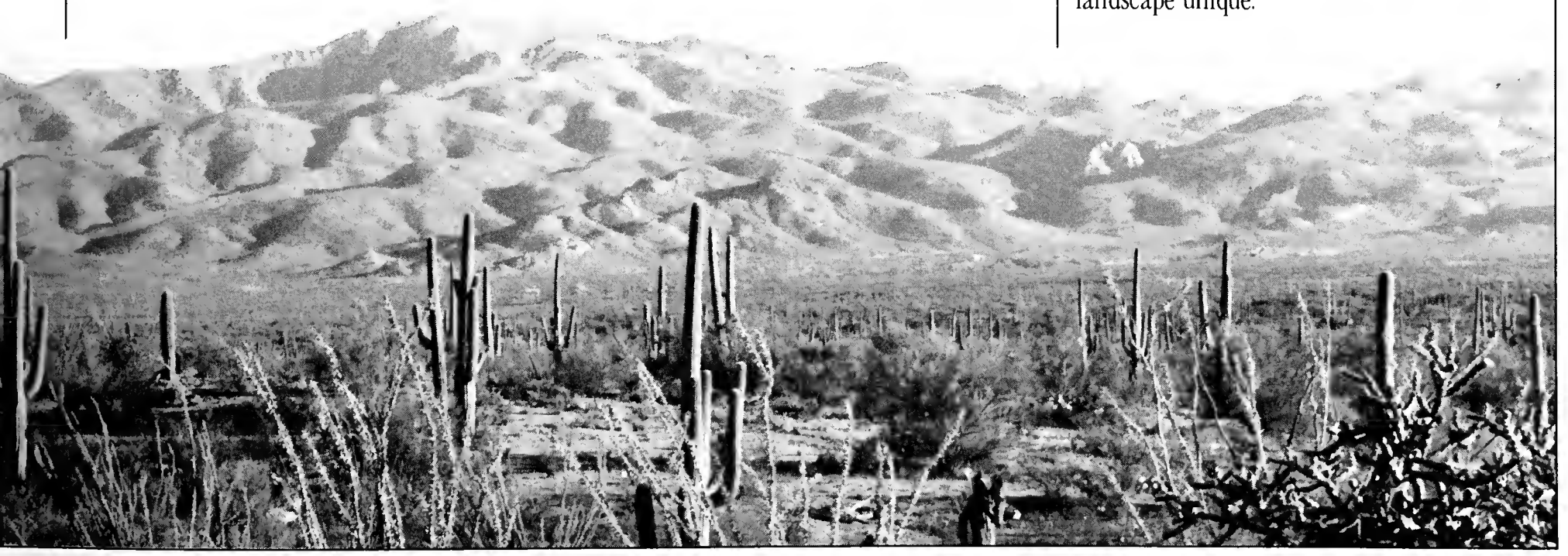
In Arizona, certain areas have had the water levels lowered a total of almost 500 feet, or more than ten feet per year since pre-development times. When outflow exceeds recharge, the system is in a deficit situation. If this situation continues, it could seriously affect plant, animal and human life in and around the Sonoran Desert.

Significant environmental and economic conditions occur as a result of groundwater declines. One of the first side effects of declining water levels is the energy cost involved in the extraction of the water. The more lift that is required to bring groundwater to the surface, the higher the energy costs will be to operate the mechanical pump. This higher price may eventually be reflected in the agricultural marketplace.

Another unfavorable result of water level decline is land subsidence and earth fissuring from the collapse and compaction of the once-saturated aquifer sediments. These problems are very troublesome in metropolitan areas and can cause millions of dollars of damage. The effect of this aquifer compaction is often irreversible — even if water should once again be available to fill the void in the compacted sediment it would generally be impossible because of the destruction of the once-available pore spaces.

The lowering of the water table also reduces or discontinues any groundwater flow that may have been entering into perennial streams in the area. This lack of ground surface water interaction along with human created diversions of the surface water away from its natural channel can turn once flowing stretches of river into dry washes. A good example is the Salt River in Phoenix, which once was a perennial river. Today, as a result of the regional lowering of the water table and upstream diversions, it has become a dry streambed which flows only when water is released from upstream dams.

The Sonoran Desert's landscape and water resources are constantly changing as a result of geological and human influences. Throughout the extensive geological time frame and the relatively short human time period many changes, both positive and negative, can be observed. Human changes have made living in the desert areas possible mainly through the use of water resources, whereas the geologic changes have made the Sonoran Desert landscape unique.



The Sonoran Desert:

THE RICH NATIVE FLORA

by Wendy C. Hodgson

Most of what we know about Sonoran Desert vegetation and floristics is the result of the work of Forrest Shreve, Thomas D. Mallery, and Ira L. Wiggins. Vegetation and Flora of the Sonoran Desert, *volumes I and II, is the result of their intensive field work.*

In nature, independent of human-imposed geo-political boundaries, there are groupings of plant species and animals that are unique to specific environmental conditions and which occur together. This assemblage of plant species is referred to as a *community.*

While the community is basically defined by the vegetation, it is much more than the sum of its constituent plant species. It is actually the sum of all the species plus their interactions.

The environmental conditions that are important in determining the boundaries of a community are climate, soil, elevation, latitude, exposure and, to some degree, the interaction of individuals — for example, competition and predation.

In the Sonoran Desert, topography can be variable and abrupt changes in elevation result in well-defined boundaries between plant communities. In Arizona this can be seen between Wickenburg and Prescott where the elevation changes rapidly from 3,000 to 5,000 feet. In level or rolling regions, however, the boundaries are not well-defined and there is a gradual transition from the desert to adjacent communities.

Slope exposure can also have a dramatic effect on vegetational composition. The saguaro *(Carnegia gigantea),* for example, is considered an indicator plant of the Sonoran Desert, yet it can be found growing on south-facing slopes at elevations as high as 4500 feet, in association with juniper and other higher elevation plants.

The amount and seasonal distribution of precipitation is perhaps the most important climatic condition limiting the boundaries of the Sonoran Desert. The northern portion of Baja California receives almost all of its rainfall during the winter months, while the southern portion of the peninsula receives most of its rain during the summer months. Winter rains form about half of the annual total at Yuma and Tucson, but further west the percentage of winter rain drops to about 25 percent.

The winter rains are gentle and prolonged and cover a large area, so that soil moisture buildup is much greater. In contrast, summer rains, which occur in July, August and September, are brief but torrential and often localized. Because they are sudden, flash flooding occurs, runoff is rapid and soil moisture buildup is lower than in winter. Summer rains are also sporadic, and periods of drought lasting 30 to 60 days are common. The number and duration of drought periods are also important. Large, non-succulent perennials can withstand such periods by tapping deep-seated soil moisture. In soils of fine texture the moisture at a depth of 6 feet is nearly constant and is affected from year to year only by very exceptional periods of drought or rain. The percentage of total annual precipitation contributed by summer rains increases across the Sonoran Desert from east to west.

When compared to the Mohave, Great Basin and Chihuahuan Deserts, the Sonoran Desert is by far the richest in number of plant forms and in variety of plant communities. Evergreen and deciduous plants are well represented, as are many species of small trees, leaf and stem succulents, semi-succulents, and two large groups of ephemeral plants which appear separately in the two rainy seasons. Mild winter temperatures and winter rains encourage growth of the winter herbaceous ephemerals. As one goes north and east into the other deserts, the diversity of life forms decreases as a result of lower rainfall, limitation of rain to a single season, and lower winter temperatures.

Shreve's subdivisions of the Sonoran Desert, based on "the natural botanical features of its several parts" are: (1) the Lower Colorado Valley (2) Arizona Upland (3) Plains of Sonora (4) Central Gulf Coast (5) Vizcaino Region and (6) Magdalena Region.

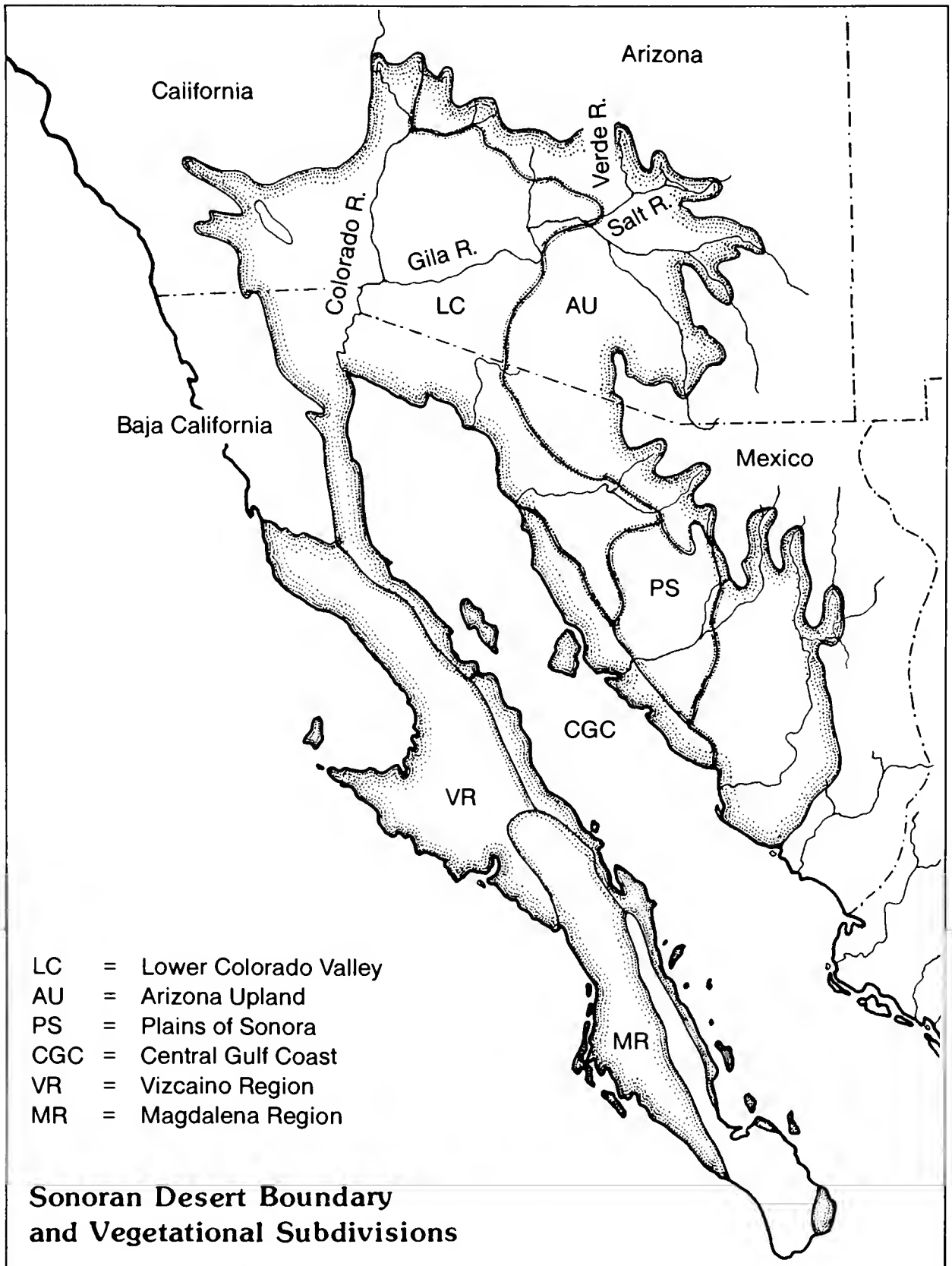
Lower Colorado Valley. This is the largest subdivision of the Sonoran Desert. Characterized by bajadas of nearly level plains, it is one of the most arid parts of the Sonoran Desert. The vegetation here is simple and is dominated by creosote and white bursage. Low, open stands of these shrubs form more than 90% of the plant population in all of the larger plains between mountains. Here, too, are the unusual parasitic plants, sandfood, *Pholisma sonorae* and *P. arenarium.* Small trees, such as mesquite, paloverde and ironwood occur on the rocky bajadas although larger specimens of the same species are found along the drainageways. The great display of winter ephemerals helps make up for the relatively poor representation of perennial plants. Phoenix lies just within this subdivision whose characteristics are still seen in South Mountain Park.

Arizona Upland. Most familiar to those who live around Phoenix and Tucson, on the south and east this subdivision merges into the Lower Colorado Valley while on the north and east it is flanked by mountains, most of which

*"Each stone, each plant, each grain of sand exists in and for itself with a clarity that is undimmed by any suggestion of a different realm." — **Edward Abbey.***

rise above levels characteristic of the desert. The vegetation surpasses that of the Lower Colorado Valley in density and variety. The dominant species are creosote, paloverde, mesquite, ironwood, ocotillo and bursage. The number of cacti is large and includes fishhook barrel, saguaro, prickly pear, cholla, hedgehog and pincushion. *Yucca* and *Agave* species, perennial grasses, large and small shrubs, and winter and summer ephemerals add considerably to the density and variety of plant life.

Plains of Sonora. This relatively small area lies between the foothills subdivision to the east and the Central Gulf Coast and Lower Colorado Valley to the west. The topography is very regular, with few mountains and hills. The rainfall is 10 to 15 inches and frost is less frequent and severe than in areas to the north. Compared to the Lower Colorado Valley, the summer temperature is also less severe. The vegetation is dominated by trees and shrubs and it is here where ironwood reaches considerable size and abundance. The area is also dominated by paloverde, mesquite and brittlebush. Here palo brea and *Fouquieria macdougalii* reach their northern limit and are abundant. Cacti are also well represented here, including the large organpipes (though saguaros are less abundant), as well as octopus cactus and *Opuntia* species, especially chain-fruit and pencil cholla. Along the banks of washes the tree and shrub cover is thick, providing shade and slightly better soil moisture conditions which favor the occurrence of many vines, root perennials, and small shrubs not found in other habitats.



Sonoran Desert Boundary and Vegetational Subdivisions

Central Gulf Coast. The rainfall here is very low and uncertain and may fall either in the latter half of the winter or in midsummer. Often there is no rain for several seasons in succession. Plants which are abundant here are thick-fleshed trees with very large trunks such as elephant trees, *Jatropha,* and the boojum tree. Also found in this area are ironwood, paloverde, ocotillo and mesquite. Evergreen shrubs include creosote, *Viscainoa geniculata,* and *Stegnosperma halimifolium.* Common deciduous shrubs include brittlebush, thornbush and *Euphorbia misera,* and succulent plants are represented by the giant cardon and a number of cholla species. Like the other subdivisions, the banks of washes are densely vegetated. Ephemeral plants are abundant on sandy soil after rains.

Vizcaino Region. The central area of Baja California is characterized by light winter rainfall which is very uncertain in much of the interior. The region is hilly with few mountain areas and many rough fields of volcanic rock. Shrubs, cacti, and stones are heavily covered with lichens, and ball moss, an epiphytic bromeliad, is abundant. Leaf succulent plants are well represented. There are several large *Agave* species and the smaller *Echeverias.* The shrubby bursage, *Ambrosia chenopodifolia,* is especially abundant giving the landscape a light gray tone. The boojum tree also very abundant on fine and coarse outwash soils and elephant tree is found primarily here, too. This subdivision is known for its unique plants, and the contrast between the areas of the richest and the poorest vegetation is greater than in any other subdivision of the Sonoran Desert.

Magdalena Region. This area includes the desert of the southern third of Baja California. The northern portion of the Magdalena is characterized by extensive fields originating from volcanic activity. The coast is bordered by lagoons and sand dunes. The interior of the plain is characterized by many playas ranging in size from several hundred acres to a few square yards in area. This region is markedly different from the Vizcaino in that it does not support the boojum tree. Abundant here except in the north, are mesquite, paloverde, fern-of-the-desert and *Jatropha.* Large cacti are also common, including the cardon.

As you can see, the Sonoran Desert is a land of tremendous contrasts and differences in its plant communities as well as its landscape. It is the most varied and complex of all the North American deserts.

Symbol of the Sonoran Desert:

THE SAGUARO

by Steve Priebe

Although the Sonoran Desert supports a great variety of plants, none is more closely identified with it than the saguaro, *Carnegeia gigantea.* A stand of these towering giants set against a backdrop of block-faulted mountains is one of nature's great architectural wonders. This image has become the symbol of the American southwest.

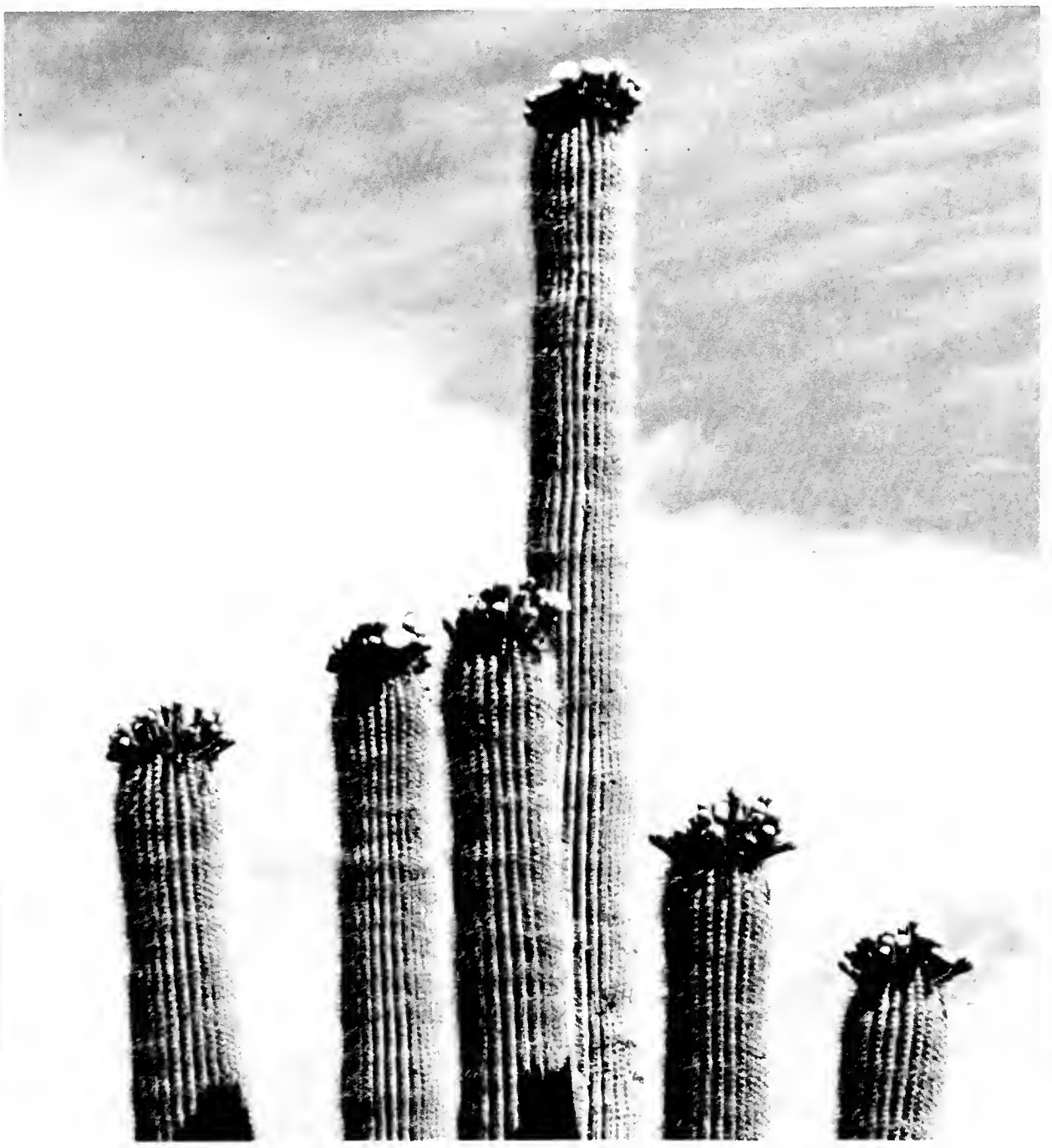
The saguaro occurs naturally only in the Sonoran Desert, and in the United States its range is limited almost entirely to the state of Arizona, although a few plants have been found in a corner of California near the Arizona border. Within these boundaries, and in their range in the states of Sonora and Sinaloa in Mexico, saguaros are found only at elevations below 4500 feet.

The great saguaro begins its life as a tiny seed no bigger than a pinpoint. And although the plant is at risk from natural forces and predators throughout its life, the species has survived and reproduced successfully for thousands of years.

In today's high-tech world it is easy to lose sight of the fact that the fate of humankind is inextricably tied to the earth. Not so very long ago, however, our dependence on the land was more direct. In the desert southwest, understanding this dependent relationship was a matter of survival.

In this beautiful but harsh environment, desert dwellers knew and used more than 400 species of wild plants. For the native O'odham and their ancestors, the Hohokam, the saguaro was important as a food staple and as part of their culture. For centuries, native people have celebrated the saguaro fruit harvest. These ceremonies were believed to be essential in bringing forth the summer rains that were needed to raise corn, squash, beans and other crops.

Those of us who are newcomers to the Sonoran Desert may not depend on the saguaro as did the O'odham and the Hohokam, but we can learn appreciation, if not reverence, for these majestic plants that once sustained life in the desert.



The fascinating phenomenon of reproduction is a story of beginnings, for in this natural cycle, there is no end.

The seed is usually thought of as the beginning of a plant's life. Sown upon the soil, it encounters a variety of conditions — temperature, moisture, and soil composition, for example. These immediate conditions influence germination and the early growth of the seed and make up what is called the micro-environment.

For many plants, the micro-environment conditions are very specific. This is particularly true of the saguaro, the indicator plant of the Sonoran Desert. The conditions that are critical for saguaro seeds to germinate occur very infrequently, and with no regularity.

In the case of the saguaro, scientists believe that when these precise conditions do occur, many thousands of seeds germinate. This theory is supported by the existence of stands of saguaros that appear to be the same age (the age of saguaros is generally estimated based on the height of the plant).

Once it has germinated, the seedling faces formidable obstacles. Drought, intense radiation from the sun, and below-freezing temperatures all take their toll on the young plants. Seedlings are also browsed by deer, rabbits and other foraging animals. Cattle grazing has dramatically affected the survival rate of saguaros too. Not only do these animals

browse the plants themselves but they also trample and graze other vegetation that might have protected the emerging plants. Saguaro seedlings have an average life expectancy of less than six weeks, and it is estimated that as many as 70 percent of them succumb to browsing.

Saguaros are often seen growing under or near another plant that is called a "nurse plant." These sheltering plants provide protection from the sun, insulation from the cold, and create a barrier against browsing animals.

"'The saguaros — they are Indians, too. You don't ever throw anything at them. If you hit them in the head with rocks you could kill them. You don't ever stick anything sharp into their skin either, or they will just dry up and die. You don't do anything to hurt them. They are Indians.'"

The Desert Smells Like Rain,
Gary Paul Nabhan

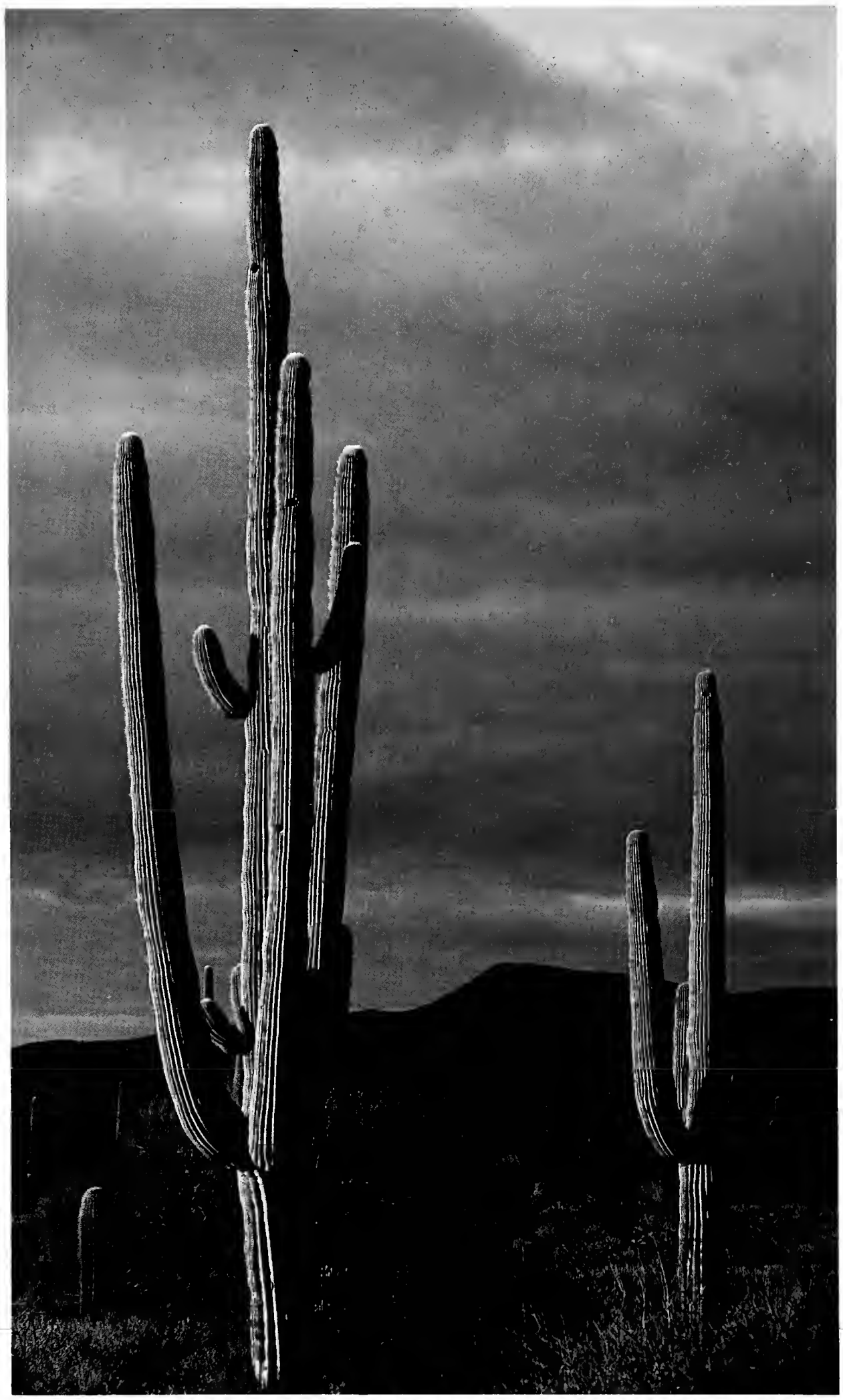
Nurse plants are critical to the establishment of saguaros, for the more exposed the area of germination, the less likely the seedling is to survive.

When one of the thousands of tiny seeds produced by a single saguaro does germinate and the seedling avoids predation, it may grow at a rate of four inches per year. This figure may vary, as one might expect, depending on soil conditions and precipitation. This is the first of three stages in the life history of the saguaro, and it is commonly called the "club" stage, though young saguaros with no arms are also called "spears." During this stage of development, all of the energy produced through photosynthesis is directed to growth in height and diameter. This stage continues until maturity, defined as the time when the plant becomes reproductively active; that is, when it begins to flower.

Flowering generally occurs when the plant is about 30 years old, or when it reaches a height of six to ten feet. Because the flowering response requires approximately 50 percent of the plant's energy, less is available for the production of new height and girth and the saguaro begins to take on a new shape. The top is not as large in diameter, and so it appears to taper slightly. This period of growth is called the "wine bottle" stage. Upward growth now slows to about an inch per year.

The third stage is characterized by the production of arms. It is generally believed that saguaros must be fifty to seventy years old before they begin to make arms. At this age, plants have reached twelve to fifteen feet in height.

Saguaro flowers, which appear in April and May, are located at or near the growing tips of the main trunk and arms. The presence of arms increases the number of growing tips, so



*"I yearned for the clarity, for the sky that stretched taut blue from horizon to horizon, where the landscape was clearer and closer, where things just made better sense." — **Ann Zwinger***

"The desert, to those who do listen, is more likely to provoke awe than to invite conquest."
—Joseph Wood Krutch

"There are hints to be had here of the way in which a land forces new habits on its dwellers."
— Mary Austin

more flowers are produced. The flowers do not all bloom at once but open over a period of four to five weeks. These flowers contain all the parts necessary to produce a fruit filled with the seeds of a new generation. However, before this can occur there must be a transfer of pollen from one flower to another, plant to plant.

The large, waxy-white saguaro flowers open late in the evening and are pollinated by bats and moths during the night, but they often persist into the early morning to take advantage of daytime pollinators such as birds and bees. These creatures seek the nourishing nectar found deep in the flowers. In the process of obtaining the nectar, they are "dusted" with pollen that is then carried and deposited on the next flower they visit. Both the pollinators and the saguaros benefit from this exchange.

Since each flower lasts less than 24 hours, pollination must occur in a relatively short time. An average saguaro (if there is such a thing) produces almost 300 flowers per season. Only about half of the flowers go to fruit, making the annual production about 150 fruits. The fruits mature over a period of 35-45 days. Ripe saguaro fruits have a red, fleshy center that contains thousands of tiny black seeds.

The seeds fall to the ground to face an uncertain fate. Some are eaten by ants and other insects. Others are washed away by summer thunderstorms. But a few fall into a crack or crevice containing suitable soil near a nurse plant that will provide the precise micro-climate for the seed to germinate and complete the cycle.

An individual saguaro may live 150 to 175 years. Unlike trees, saguaros have no growth rings, so a precise determination of age is impossible. Some saguaros attain a height of 40 feet, and an elderly plant that has many arms can weigh as much as ten tons. Because of their massive size, age and weight are sometimes exaggerated.

In the course of its lifetime, a saguaro will produce more than 30 million seeds. Of these, it is estimated that only one will survive to maturity and complete the life cycle.

> "The journey's end of successive adaptations is found in the saguaro."
>
> *Mary Austin*

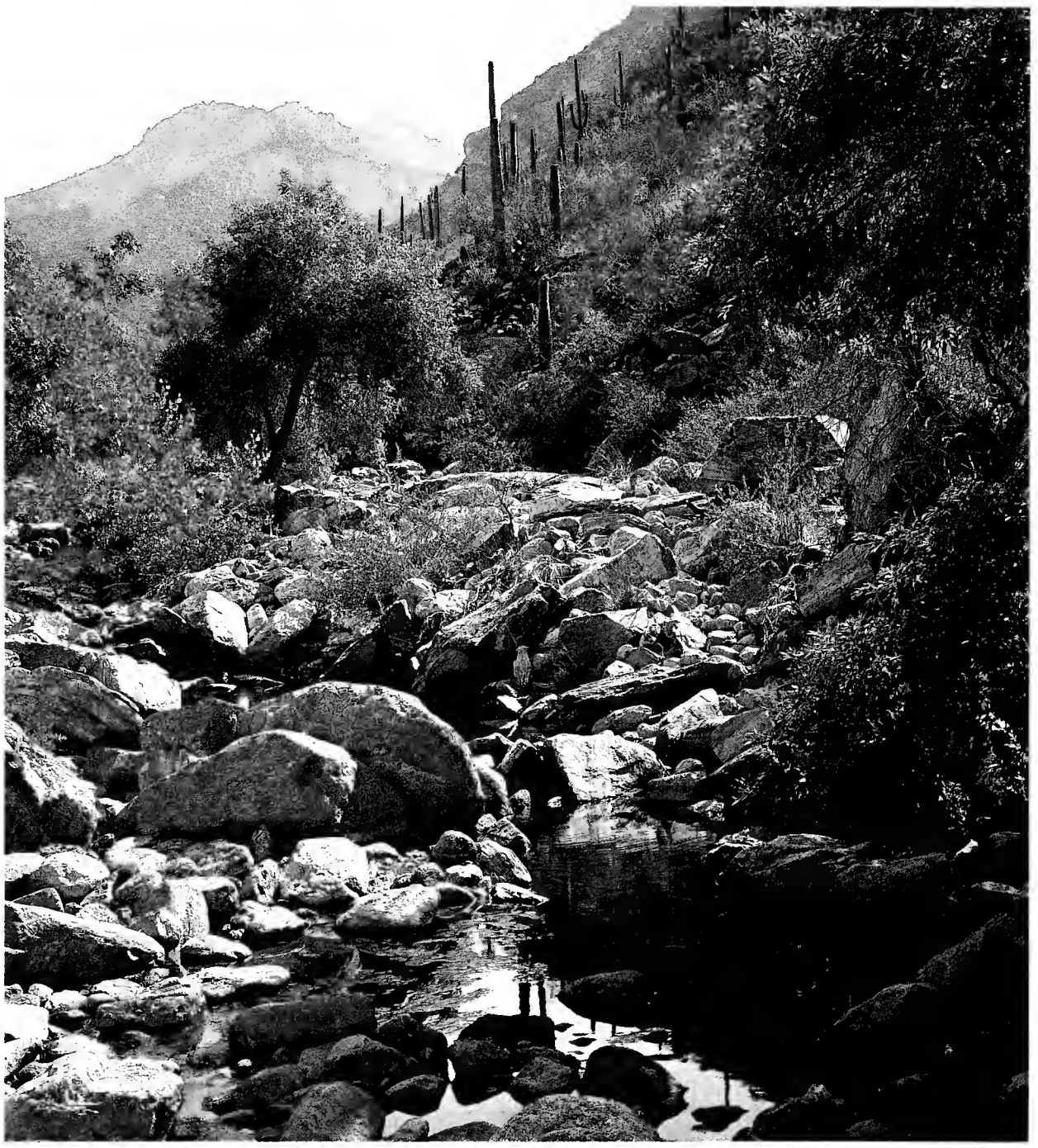
Its limited range alone is enough to warrant protection for this magnificent plant, and if saguaros are to withstand the impact of human activity in the Sonoran Desert, conservation and preservation measures are urgently needed. We have learned a great deal about the saguaro, its distribution and its capacity to reproduce. Now we must act to ensure its survival.

Note: Arizona's Native Plant Law is designed to protect threatened and endangered plants. For specific information, contact the Arizona Commission of Agriculture and Horticulture.

The Sonoran Desert Oasis:

PRESENT, PAST, FUTURE

by Ruth Greenhouse



THE CITY ... A MODERN OASIS

A recent visitor to the Desert Botanical Garden asked incredulously, "Where in the world does a desert city as large and as green as Phoenix get its water?"

This is a good question. Here in the Valley of the Sun there are no obvious indicators of our water status.

During periods of drought in the midwestern United States the signs are apparent: rain doesn't fall, river levels drop, lawns and fields dry up. But in the desert where it rarely rains and no river currently flows, we always seem to have enough water to support agriculture, industry and our current population of 1.5 million.

Using the ancient definition of oasis (*to dwell* and *to drink*) the greater Phoenix area is indeed an oasis in the desert. But where do we get our water?

A map shows the major canals that bring water to the city from two desert rivers, the Salt and the Verde, both of which originate outside the desert itself. The Salt and the Verde collect snowmelt and rain from a 13,000 square mile watershed which ranges from Flagstaff in the north almost to the New Mexico border in the east.

A series of dams built between 1905 and 1946 allows us to store the river water in six reservoirs located northeast of Phoenix. Over 1200 miles of canals, laterals and ditches supply water around the city. This seemingly steady supply of surface water has allowed Phoenix to thrive and grow.

Today, however, about one-third of the water we consume is pumped from underground aquifers, and there is growing concern about the future. What will we do in case of a drought? Do we have enough water to support unlimited growth? How can we prevent the continuing contamination of our water supplies? Do we wish to further degrade or alter the few remaining natural streams in the Salt and Verde watershed?

A LOOK AT THE PAST

Let us look at the sources of our water from a different perspective, one that takes us to the rivers themselves. To imagine what the Salt River valley looked like before humans altered the environment we would have to go back in time before 300 B.C. when the Hohokam first began irrigating their fields of corn, beans, squash, gourds and cotton with water from the Salt River. During their 1700 year residence here, the Hohokam built approximately 300 miles of canals, some of which are part of our modern canal system.

The first Anglo farmers in the 1800's faced the same challenges and opportunities as the Hohokam: a river that was sometimes merely a trickle and other times a torrent as it responded to periods of drought, spring snowmelt, summer storms and yearly changes in precipitation. The Salt/Verde watershed averages twenty inches of moisture a year, almost three times the seven inches received in the Phoenix area. However, averages take into account many years of rainfall and can be misleading. The actual amounts of precipitation are extremely variable, sometimes differing tenfold from one year to the next.

Still, in the age before dams and other drastic contemporary forms of utilization, there was significantly less alteration to the environment. In fact, it is estimated that only 5 to 15 percent of Arizona's original riparian (streamside) acreage remains in a natural form today. Perhaps we should consider ourselves lucky that pristine desert oasis habitats still exist at all. We can draw upon our knowledge of them to envision the Salt River

as it once was, a shimmering corridor of life-giving water, meandering through the valley. It supported the same communities of plants and animals found today in natural riparian habitats, although with greater abundance and without the species that have since been introduced from other parts of the world.

The riparian vegetation that grows along the banks of rivers and in the floodplains is different than that in the surrounding desert. These plants thrive in moist, fine soil rather than in dry, rocky places. Most are phreatophytes: that is, they must have their roots in groundwater or in the wet soil above a water table. The diverse vegetation includes gallery forests of Fremont cottonwood and Goodding willow trees which are considered to be the rarest forest type in North America. (Gallery forests, sometimes called fringing forests, grow along water courses in regions otherwise devoid of trees.)

The diversity of vegetation in these forests provides food and shelter for more than 75 pecent of the vertebrartes found in the Southwest. More birds nest here than in any other habitat in North America. The roots of these trees, especially the small roots of the willow, help prevent erosion, thereby maintaining the integrity of the streams and their flow.

In addition to gallery forests, other plant communities such as marshes, floodplains and mesquite bosques are associated with oasis habitats. Each supports its own unique variety of plants and animals and contributes in some way to the total ecosystem. For example, cattails which grow in marshes and provide food and shelter for many species of fish and birds, also help improve water quality by filtering contaminants.

"The rivers are dead. Their biotic communities are gone. Their fragile watersheds have collapsed during decades of abuse."

Amadeo M. Rea

Mesquite trees reach their greatest development at the confluence of water courses or in old floodplains. Here they grow in bosques, or small forests. Mesquite bean pods are eaten by many desert animals and they were a major wild food staple for human desert dwellers in the past.

Mesquite bosques have all but disappeared in the last century as a result of clearing, wood harvesting, and a reduction in their water supply from damming streams and pumping groundwater. Today, stands of mature mesquite trees are the fourth rarest of 104 types of plant communities identified in the United States.

A LOOK TO THE FUTURE

More and more we are recognizing the practical and philosophical benefits of preserving and restoring riparian habitats. Today, Arizona's streams and wetlands comprise less than one half of one percent of the state's landscape, and they are in imminent danger of further reduction. There are two issues at stake here which are closely interrelated: the human need for water and the status of the environment. People care about both.

As cities like Phoenix grow, a balance must be reached between the exploitation and conservation of many of our resources, especially water. We know that our supply of water is limited and that it would be seriously stressed by a drought. Water management specialists encourage water conservation methods such as the use of effluent and the limitation of wasteful water practices.

Municipal programs are addressing critical issues such as the depletion and contamination of groundwater and the construction of artificial water features by developers. No doubt discussions will continue as to the amount and type of urban, industrial and agricultural growth our water supplies can really support without irreparably degrading or depleting these sources.

Nearly as important as our practical need for water is the fact that people seek out water and wet areas for recreation, rest and renewal. Even our man-made amenities are an attraction. Resident Arizonans and visitors alike enjoy the swimming, fishing and water sports that the reservoirs provide, and they use the city's canal banks for biking, jogging, and fishing. There is even an encouraging trend to revegetate the cleared banks of the cement-lined canals with native plants to make them more appealing.

While the aesthetic appearance of canals, reservoirs, parks, flood control channels and other necessities can be significantly improved by preserving and restoring native vegetation, none of these artificial water features can equal the appeal of natural desert oases. Every year, millions of visitors are drawn to them to enjoy their beauty, richness, and serenity.

Ironically, these areas are most in danger of being destroyed, not just by impoundment or other adversary land use practices. Perennial streams and wetlands disappear as groundwater pumping drains water from their supporting aquifers and other practices alter their hydrology. And although riparian protection conservation programs are being initiated by both municipal and private institutions, these efforts will only succeed if they have broad public support.

We have reached a critical point in the history of the Sonoran Desert. During the past few decades we have experienced higher than average amounts of rainfall. Historically, however, dry cycles and water shortages are much more common. Humans can do little or nothing to control the amount of rain and snow that feeds the surface water, but we can have an impact on how efficiently and responsibly this water is used.

When urban planners are allocating water resources it is imperative that they take into account the impact of their decisions on the entire ecosystem. The choices that they make will determine not only the quality of our lives, but also the fate of the plants and wildlife with which we share the Sonoran Desert.

LITERATURE OF THE SONORAN DESERT

The quotations from desert writers in this issue of *Agave* magazine are intended to involve readers in some of the literature of the Sonoran Desert. The selections are by Jane B. Cole, Desert Botanical Garden librarian.

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